feet long, to which are attached ¼" blocks of 15 per cent boron steel in 4 inch lengths. The rod is mounted on lateral wheels **80** operating on tracks **81** on platform **33** outside of the reactor and on the bottom of slot **72** inside the reactor. The composite rod is provided with a rack **82** engaged by pinion **83**. This pinion is driven by belt **84** from a differential gear box **84a** in opposite directions by in motor **85** and out motor **86**. Limit switches **87** and **87a** are positioned to break the common motor lead at either end of the rod travel by contact of stop **88**. The motors **85** and **86** are under control of the operator, and the action of the control rod is fully described in a subsequent section of this specification. A "selsyn" indicator system **86a** is used with the indicator in view of the control rod operator to tell the operator the exact position of the control rod at all times. The indicator may be calibrated as discussed later.

The "shim" or limiting rod **30** is shown in Fig. 19. This rod may be simply a cadmium sheet 1/16" by 3½" by 15 feet riveted to a fiber backing, movable by hand into and out of the reactor, held in place by pin **89** and locked by pin guard **90** and padlock **91**. This rod is so positioned in the reactor that when the control rod is completely out of the reactor the maximum reproduction ratio cannot exceed a value dependent upon the position of the shim rod.

The two safety rods **41** are alike and one is shown in Fig. 18. They are formed from 1/16" cadmium sheet 3½" wide backed by fiber, and long enough to completely cross the reactor. They are drawn into the reactor from platform **42** by cable **92** passing over pulley **93**, the cable also carrying weight **94**. The safety rods are normally held out of the reactor by latch **95** opened by spring **96** and held in latched position by current passing through solenoid **97**. Accidental or deliberate interruption of current in solenoid **97** will cause the latch to open and the safety rods will be pulled into reactor by gravity to stop the reaction. Spring bumper **98** cushions the rod at the end of its travel. Normally when the reactor is left unattended, all rods are inserted fully into the reactor. The above described reactor is capable of being operated at an output as high as 10,000 kilowatts for short periods. Since the reactor is only conductively cooled, only small powers can be continuously maintained without an appreciable internal temperature rise. However, the reactor is valuable for the manufacture of radioactive elements and $94^{239}$ and subsequent removal of the irradiated uranium by use of the removable section, for use as an intense source of neutrons available in well **21** and shaft **26** (Fig. 8), as a generator of high energy gamma rays, and as a means for testing materials by use of the removable stringers. These uses are more fully described later in the section on uses of neutronic reactors.

The power produced by the reactor at any attained neutron density may also be calculated from measurements on standard indium foils in locations spaced across the reactor. Again using the symbol $A_0$ for the saturation radioactivity value computed from the counts per minute obtained in a Geiger counter from the standard indium foils distributed across the pile, and assuming the total energy produced per fission is 200 million electron volts (m. e. v.), equivalent to $3.2\times10^{-4}$ ergs, the power of the pile at the measurement location is given by the following formula:

$$\text{Power}=2.3A_0\ \text{ergs/sec.}=2.3\times10^{-7}\times A_0\ \text{watts}$$

Such indium foil measurements can be used to accurately calibrate galvanometer **70** in terms of watts, if desired. The power can be removed as heat from neutronic reactors by the use of suitable circulating media if desired, as will be taken up later.

A prototype of the reactor as above described was built in a slightly non-spherical shape, and successfully operated to create a self-sustaining chain reaction at about 200 watts power. This reactor was then torn down and a large portion thereof incorporated in the reactor just previously described.

As originally operated, the active portion of the reactor was not cubical but was substantially in the shape of a flattened rotational ellipsoid with a polar semi-axis of 309 centimeters and an equatorial semi-axis of 388 centimeters as shown diagrammatically in Fig. 42. The effective radius was about 355 centimeters (12.7 feet) and the average K constant was about 1.054. It was surrounded by about 12 inches of graphite and supported by a wooden framework.

The uranium in the reactor was as follows:

| Geometrical Shape | Compound | Weight, lbs. | Density, gm./cm.³ | Number | Total Weight in Reactor, lbs. |
|---|---|---|---|---|---|
| 2¼" cylinder | Metal | 6.0 | 18 | 2,060 | 12,400 |
| 3¼" pseudosphere | $UO_2$ | 4.72 | 6.10 | 14,840 | 70,000 |
| Do | $U_3O_8$ | 3.99 | 5.17 | 1,200 | 4,790 |
| 3" cylinder | $UO_2$ | 4.56 | 6.14 | 540 | 2,460 |
| Do | $U_3O_8$ | 3.97 | 5.20 | 840 | 3,340 |
| | | | | 19,480 | [1] 92,990 |

[1] Equals 46.5 tons.

Various grades and makes of graphite were used in the reactor, the reflector and a pier extending upwardly for use as a thermal neutron source. The graphite, in the amount of 385.5 tons, was made from raw materials selected to give a K reduction which averaged about .02.

As this reactor was built up the neutron activity was also monitored with indium foil exposures as above described. However, in this case, the changing shape of the reactor must be taken into account.

In this reactor, $R^2_{eff}$ is the effective radius of the structure at various stages during construction. It is given by the formula

$$\frac{3}{R^2_{eff}}=\frac{1}{a^2}+\frac{1}{b^2}+\frac{1}{c^2} \qquad (13)$$

where $a$, $b$, $c$ are the sides of a rectangular parallelopiped which is drawn to conform as closely as possible to the actual shape of the structure in its various stages of construction. If a structure employing a geometry giving K exactly unity is built up gradually maintaining a true spherical shape, then $A_0$ increases approximately at $R^2$, where R is the radius of the sphere at any time. If it is built with an ellipsoidal shape, Then $A_0$ increases approximately as $R^2_{eff}$, and in the actual structure that is built, approximate values of $a$, $b$, $c$, to agree with the actual shape at any stage can be estimated, and $R^2_{eff}$ calculated.

The values of $R^2_{eff}$ are then used to plot

$$\frac{R^2_{eff}}{A_0}$$

against layers to predict the critical layer as shown in Fig. 21.

This reactor became chain reacting after the 57th layer was added, this being about one layer beyond critical size. With 57 layers in position, the time for doubling the reaction was found to be about 1 minute. The reactor construction was started to provide a spherical shape. While the K factor of the bulk of the metal and the graphite, and the oxide and graphite, was known from exponential pile measurement, a substantial amount